
**David L. Conrad**
Larry Buss
Greg Gomez
Amit Mahadevia
Manuel A. Perotin
John van de Lindt

MIDWEST FLOODS of 2008 IN IOWA & WISCONSIN

# 3 Residential, Historic, and Commercial Buildings

*Chapter 1 described the magnitude, duration, and geographic extent of damage of the 2008 Midwest floods. Many areas experienced the worst flood in their recorded history with rivers cresting at unprecedented levels and flood elevations exceeding those anticipated during a design event, forcing tens of thousands of people to be evacuated from their homes. While the flooding affected seven states in the Midwest (South Dakota, Minnesota, Wisconsin, Nebraska, Illinois, Indiana, and Iowa), the most damage occurred in Iowa and Wisconsin.*

The MAT observed damages to residential, historic, and commercial buildings, as well as critical and essential facilities in the most affected Iowa and Wisconsin cities. Occupancy categories for buildings and other structures are defined by the American Society of Civil Engineers in two standards: ASCE 7, *Minimum Design Loads for Buildings and Other Structures,* and ASCE 24, *Flood Resistant*

*Design and Construction.* Chapter 3 of this MAT Report discusses Categories I and II (residential, historic, and commercial buildings); Chapter 4 discusses Categories III and IV (critical and essential facilities). Table 3-1 describes the ASCE occupancy categories.

**Table 3-1. ASCE Occupancy Categories**

| Category | Nature of Occupancy |
|---|---|
| I | Buildings and other structures that represent a low hazard to human life in the event of failure including, but not limited to:<br>■ Agricultural facilities<br>■ Certain temporary facilities<br>■ Minor storage facilities |
| II | All buildings and other structures except those listed in Categories, I, III, and IV |
| III | Buildings and other structures that represent a substantial hazard to human life in the event of failure including, but not limited to:<br>■ Buildings and other structures where more than 300 people congregate in one area<br>■ Buildings and other structures with day-care facilities with capacity greater than 150<br>■ Buildings and other structures with elementary school or secondary school facilities with capacity greater than 250<br>■ Buildings and other structures with a capacity greater than 500 for colleges or adult education facilities<br>■ Health care facilities with a capacity of 50 or more resident patients but not having surgery or emergency treatment facilities<br>■ Jails and detention facilities<br>■ Power generating stations and other public utility facilities not included in Category IV<br>Buildings and other structures not included in Category IV (including, but not limited to facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, hazardous waste, or explosives) containing sufficient quantities of hazardous materials considered to be dangerous to the public if released.<br>Buildings and other structures containing hazardous materials shall be eligible for classification as Category II structures if it can be demonstrated to the satisfaction of the authority having jurisdiction by a hazard assessment as described in ASCE 24-05, *Flood Resistant Design and Construction*, Section 1.5.2 that a release of the hazardous material does not pose a threat to the public. |
| IV | Buildings and other structures designated as essential facilities including, but not limited to:<br>■ Hospitals and other health care facilities having surgery or emergency treatment facilities<br>■ Fire, rescue, ambulance, and police stations and emergency vehicle garages<br>■ Designated earthquake, hurricane, or other emergency shelters<br>■ Designated emergency preparedness, communication, and operation centers and other facilities required for emergency response<br>■ Power generating stations and other public utility facilities required in an emergency |

Table 3-1. ASCE Occupancy Categories (continued)

| Category | Nature of Occupancy |
|---|---|
| IV (cont.) | ■ Ancillary structures (including but not limited to, communication towers, fuel storage tanks, cooling towers, electrical substation structures, fire water storage tanks or other structures housing or supporting water, or other fire-suppression material or equipment) required for operations of Category IV structures during an emergency<br>■ Aviation control towers, air traffic control centers, and emergency aircraft hangars<br>■ Water storage facilities and pump structures required to maintain water pressure for fire suppression<br>■ Buildings and other structures having critical national defense functions<br>Buildings and other structures (including but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, hazardous waste, or explosives) containing extremely hazardous materials where the quantity of the material exceeds a threshold quantity established by the authority having jurisdiction.<br>Buildings and other structures containing extremely hazardous materials shall be eligible for classification as Category II structures if it can be demonstrated to the satisfaction of the authority having jurisdiction by a hazard assessment as described in ASCE 24-05, *Flood Resistant Design and Construction*, Section 1.5.2 that a release of the extremely hazardous material does not pose a threat to the public. This reduced classification shall not be permitted if the buildings or other structure also function as essential facilities. |

In detailing the damages observed by the MAT, Chapter 3 points out the importance of adhering to construction regulations and guidance involving such issues as foundation construction and anchoring, openings in foundation walls, elevation of new and existing facilities, placement of utility equipment, load path continuity, basements, mold and contamination, and regulatory requirements and actions. Chapter 3 also notes opportunities for building mitigation.

As noted in Chapter 1, site visits were conducted in Iowa and Wisconsin in August and September of 2008. As part of these site visits, information was gathered from local officials, facility managers, and homeowners, and photographs were provided to and taken by team members.

The city of Cedar Rapids was the most heavily impacted of any community visited by the MAT. The city encountered some of the most dramatic and costly damage due to the amount of infrastructure in the inundation area as well as the depth and duration of the flood. Figure 3-1 shows the downtown area inundated by floodwater and the associated flood zone map.

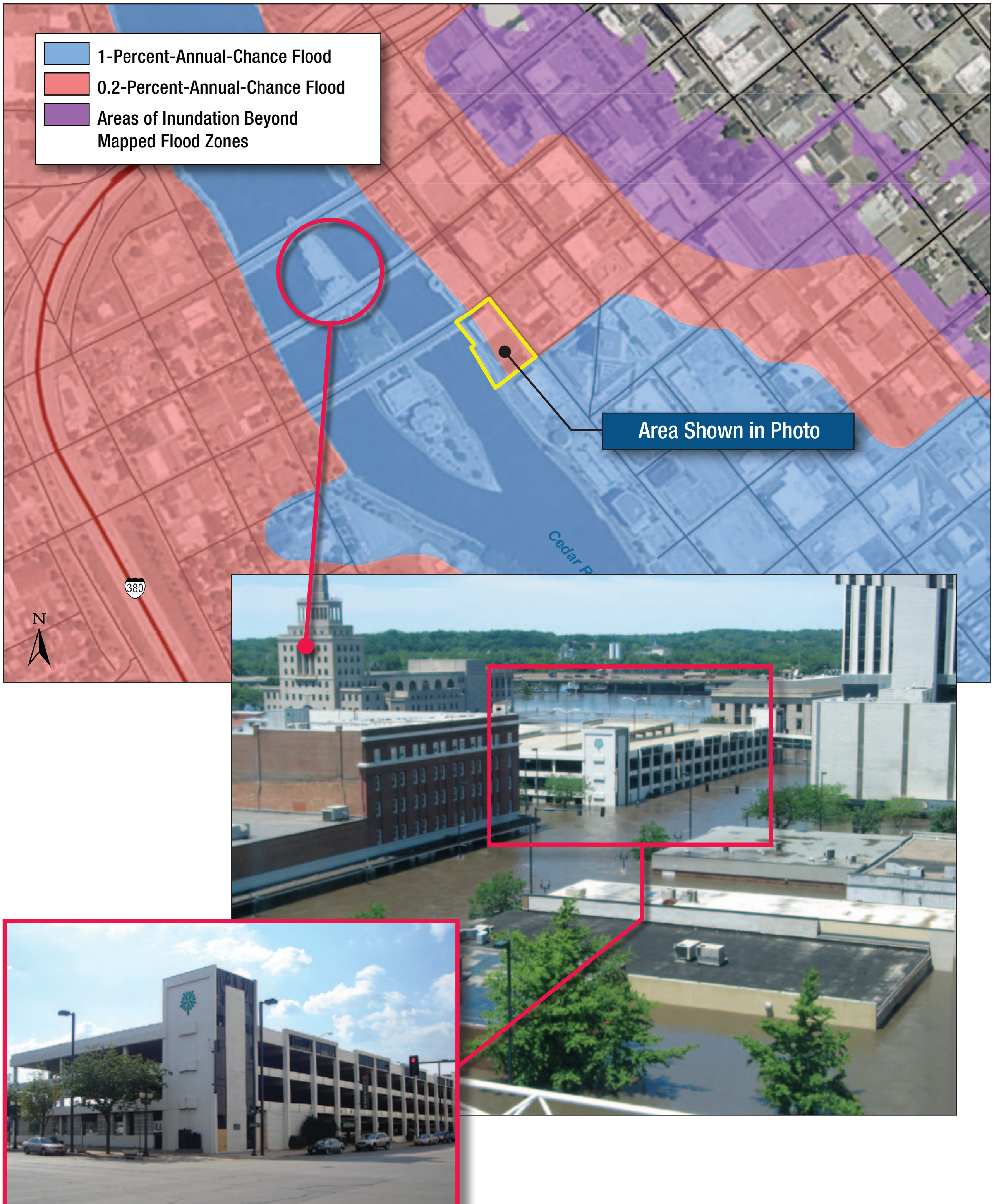



Figure 3-1.
Floodwater in the downtown Cedar Rapids commercial district exceeded 6 feet in several buildings, as shown by the parking facility and surrounding properties (Cedar Rapids, Iowa).

Figure 3-2 shows two buildings at the outer edge of the 0.2-percent-annual-chance flood zone (see also Figure 3-3). The waters were 4 feet above the first floor elevation at this location. This example highlights the residual risk and possibility of unexpected damage anywhere adjacent to even the 0.2-percent-annual-chance floodplain.


Figure 3-2.
Floodwaters covered 1,300 blocks and 9.2 square miles of Cedar Rapids (Cedar Rapids, Iowa).

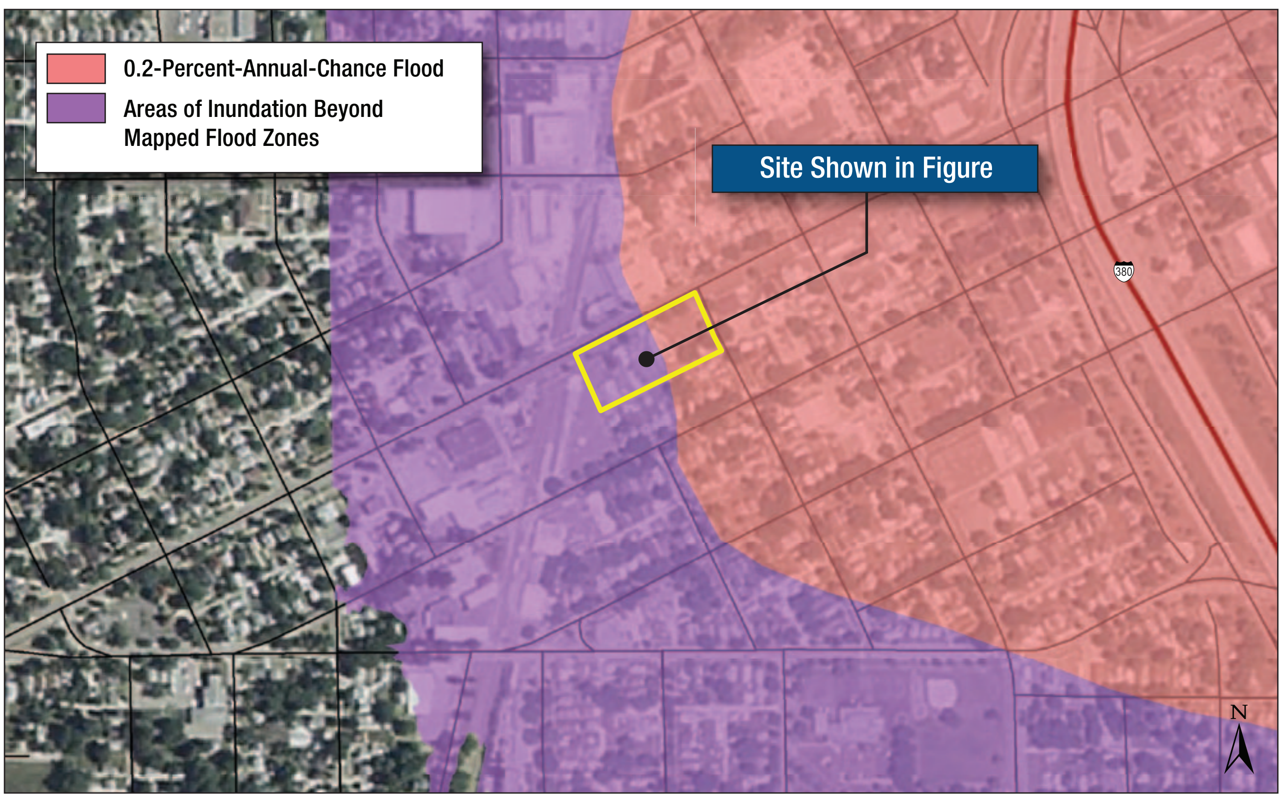



Figure 3-3.
Location of commercial buildings shown above at the outer edge of the 0.2-percent-annual-chance flood zone (Cedar Rapids, Iowa).

Several other communities visited by the MAT also experienced flooding, although not as widespread as in Cedar Rapids, that exceeded the 0.2-percent-annual-chance flood. Figures 3-4 to 3-10 illustrate different magnitudes of flooding throughout areas visited by the MAT.

Figure 3-4.
Inundation in Gays Mills, Wisconsin, where most of the town including all of Main Street is located in the SFHA. Most buildings along Main Street experienced 3 to 5 feet of flooding.


Figure 3-5.
Commercial and residential buildings in Rock Springs, Wisconsin, along the Baraboo River where the flood was estimated to be a 0.2-percent-annual-chance flood were inundated with over 4 feet of water (dashed red line indicates the water line).

Figure 3-6.
This house in Oakville, Iowa, a community protected by a levee that was overtopped by the Iowa River, was flooded with over 7 feet of water.

Figure 3-7. Buildings located within the SFHA along the Rock River in Rock County, Wisconsin, where the flood is estimated to have exceeded the 1-percent-annual-chance flood, experienced 2 to 4 feet of flooding.

Figure 3-8.
The recently developed Coralville Conference Center (outlined in red) downstream of the Coralville Dam (outlined in blue) implemented emergency protective measures, primarily sandbags, to limit flooding to a few inches of water on the main floor (Coralville, Iowa).

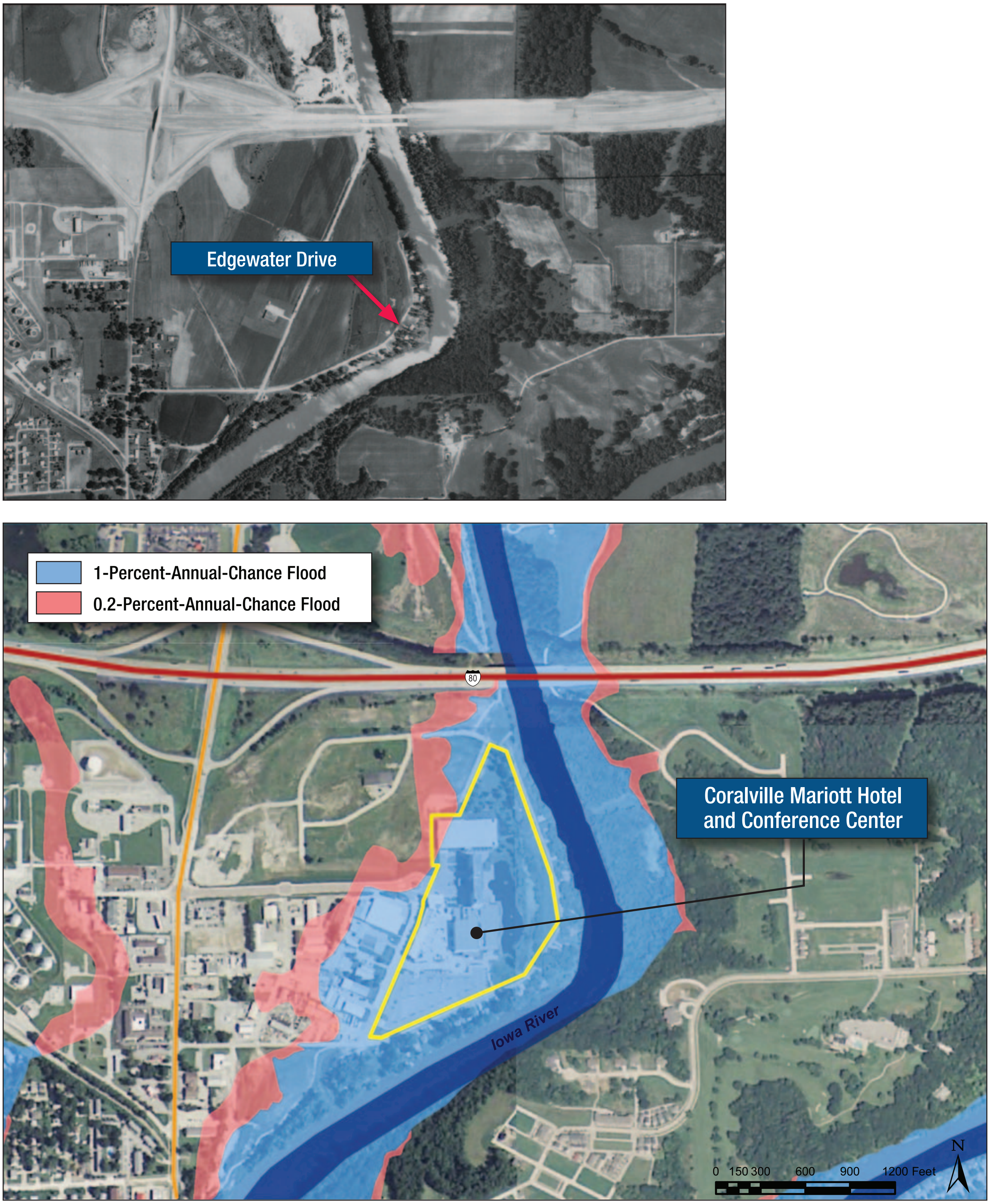



Figure 3-9.
The Coralville Conference Center is located on the former site of Edgewater Park and in the SFHA, 3 feet above the BFE. The two aerials reflect the development along Edgewater Drive over the past four decades (Coralville, Iowa).


Figure 3-10.
Although the Conference Center suffered minor damage, the adjacent buildings had extensive interior damage on the first floor (Coralville, Iowa).

## 3.1 Residential Properties

As previously noted in this report, residential structures were subject to a greater than design level of flooding in several communities visited by the MAT. Figure 3-11 shows a Cedar Rapids residential neighborhood in the 0.2-percent-annual-chance floodplain that had several feet of inundation. Flooding in Iowa and Wisconsin caused both velocity-flow and inundation damage; however, most of the damage was due to slow rising inundation. Due to high levels of soil saturation, these floodwaters also remained for weeks in some areas, much longer than typical flood events. The duration impacted recovery operations and hindered owners from returning to their properties to limit mold growth and further damages to their facility. The areas impacted by high-velocity flow were near floodways, at overtopped/breached levees, or near areas of flood flow constriction. The MAT surveyed single and multi-family residences, including some that were under repair at the time of the MAT visit and some that had been constructed subsequent to the flood event. The MAT also looked at several examples of residential elevation and acquisition projects, and two locations that had been developed and removed from the SFHA by an approved LOMR-F.

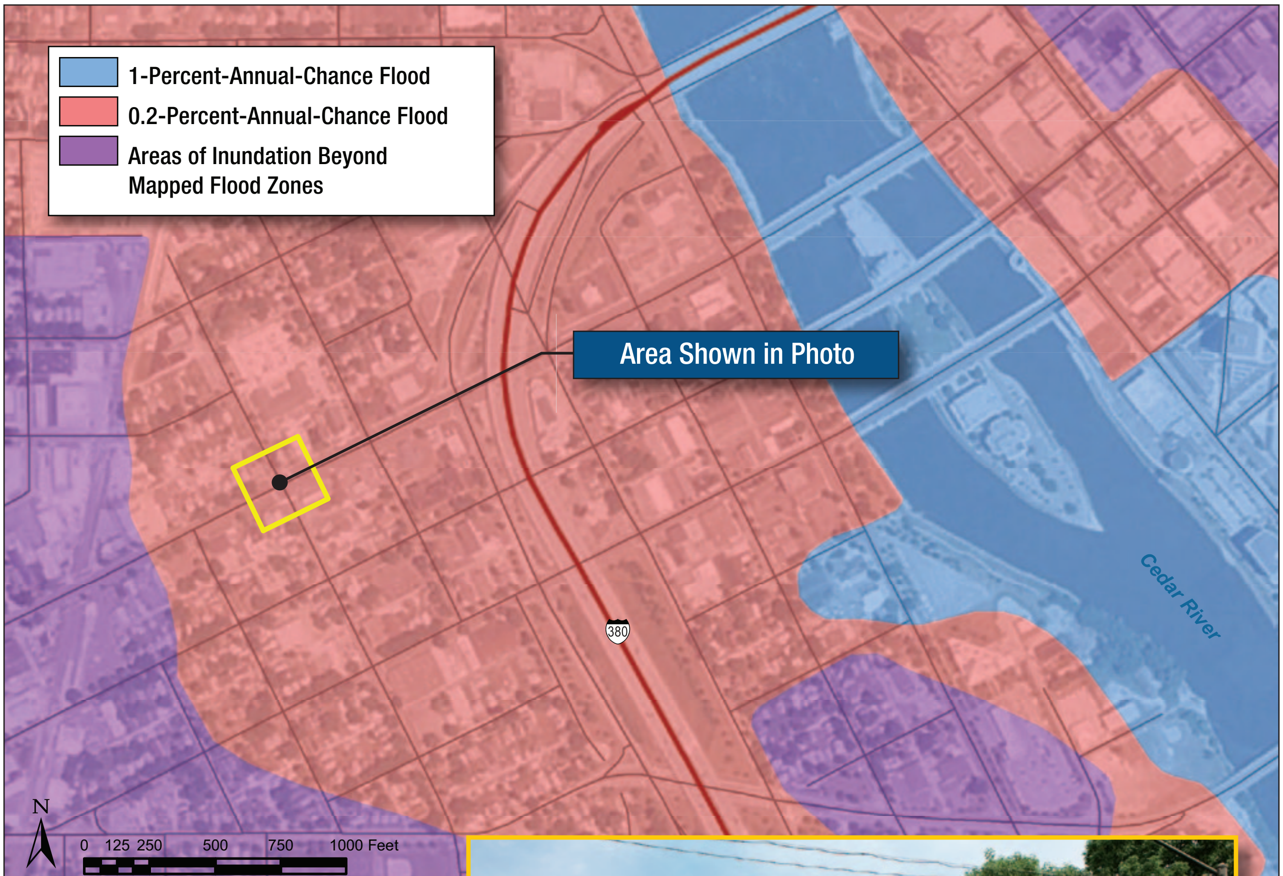



Figure 3-11.
Floodwaters in a residential area of Cedar Rapids during the flood (Cedar Rapids, Iowa).

Communities conducted inspections and tagged buildings to allow citizens back into safe homes and businesses as quickly as possible, while keeping people out of unsafe structures (see Figure 3-12). The magnitude of the event forced several jurisdictions to train and/or contract new staff to assist with damage assessments and code enforcement after the event. Several communities including Cedar Rapids and Oakville in Iowa, and Gays Mills in Wisconsin experienced flooding that required a substantial damage determination on practically every home because almost the entire SFHA was flooded. In Iowa, over 3,000 Residential Substantial Damage Estimate (RSDE) inspections were completed in the Cedar Rapids area alone, approximately half of which were deemed substantially damaged. Several communities contacted local home builders associations to help identify qualified personnel, trained the personnel, and used them to support code enforcement for repairs and reconstruction.

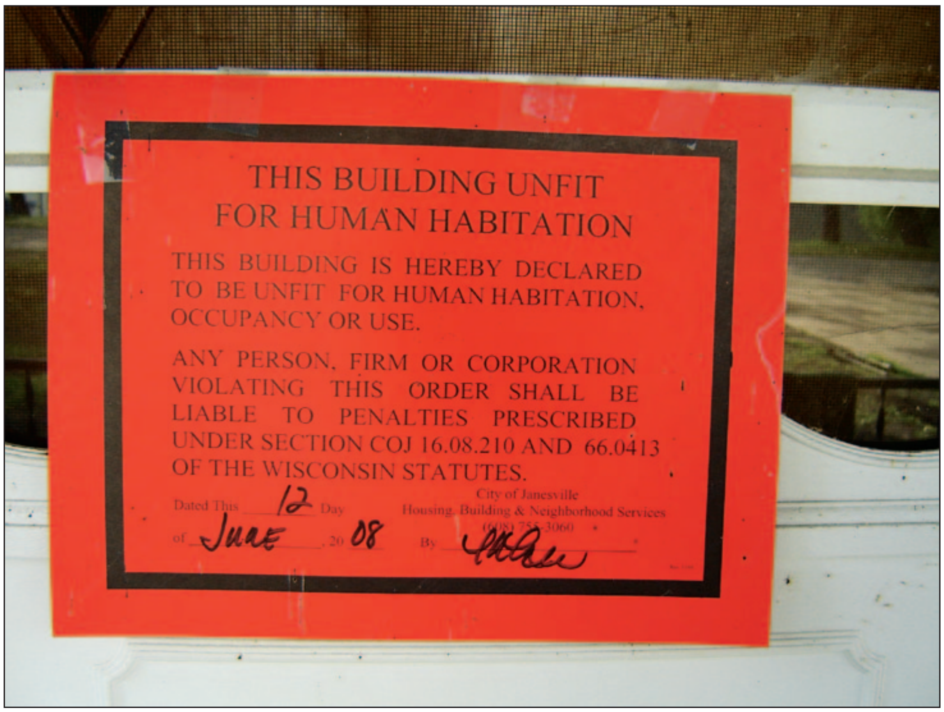



Figure 3-12.
Sample placard for a building that was deemed unsafe to enter by inspectors (Janesville, Wisconsin).

## 3.1.1 Overview of Damages

There was significant damage to homes in the SFHA throughout the areas visited by the MAT in Iowa and Wisconsin. Figure 3-13 provides a location map for the flood damaged homes located adjacent to the Cedar River that are shown in Figures 3-14 through 3-17.

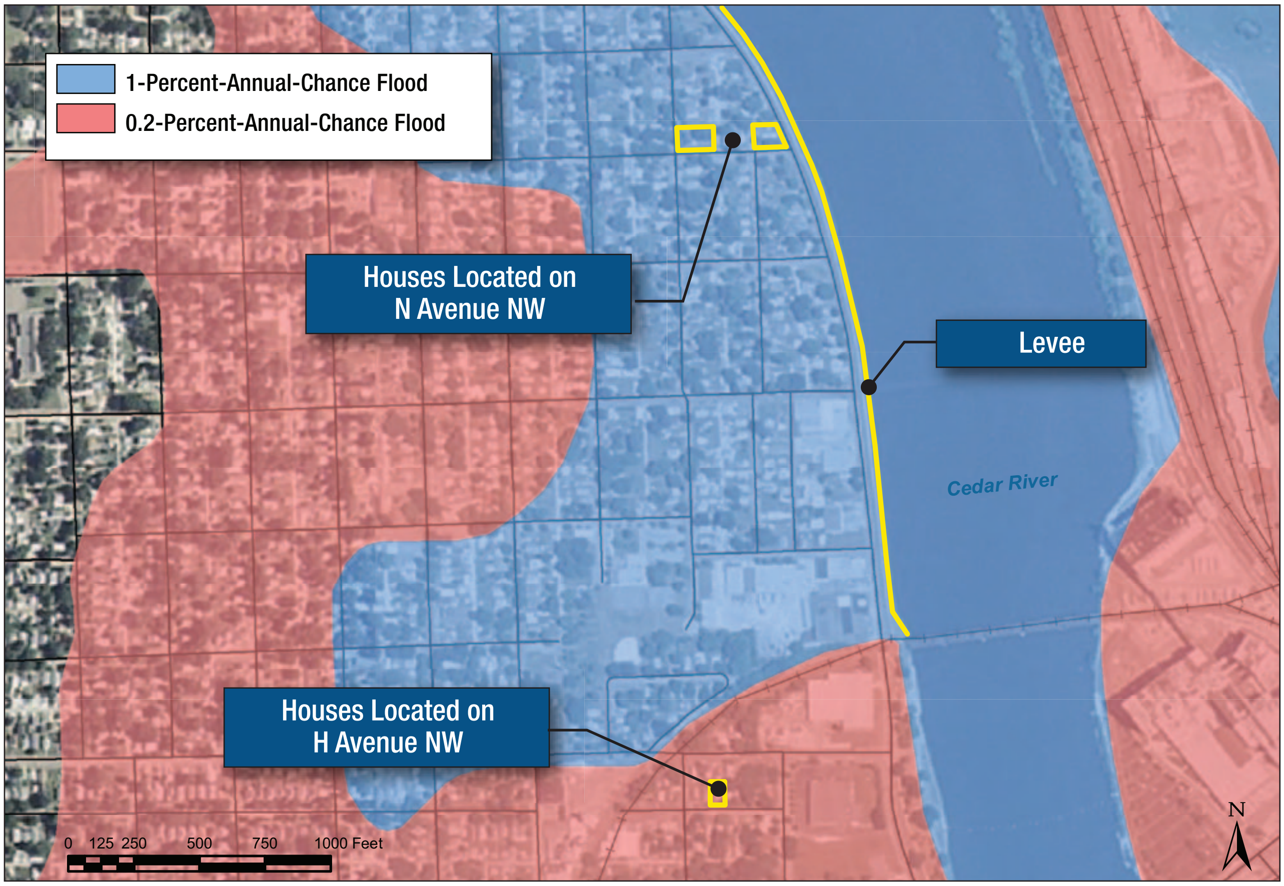



Figure 3-13. Location map for Figures 3-14 through 3-17 (Cedar Rapids, Iowa).

Figure 3-14.
Pre-FIRM house located in the SFHA at N Avenue NW. Floodwater reached the eaves of these houses located a few blocks from a levee (red line indicates flood level) (Cedar Rapids, Iowa).

Figure 3-15.
Pre-FIRM home at N Avenue NW located in the SFHA. Water marks near top of door and window frame. Marks are several feet above the levee seen in the background (Cedar Rapids, Iowa).

Figure 3-16.
Pre-FIRM house at H Avenue NW. Floodwaters reached the ceiling of the first floor in this house located outside the SFHA (Cedar Rapids, Iowa).

Figure 3-17.
This is another view of the house in Figure 3-16. The side wall and the adjacent structures are displaced in a way that suggests high-velocity water flows through this neighborhood (Cedar Rapids, Iowa).

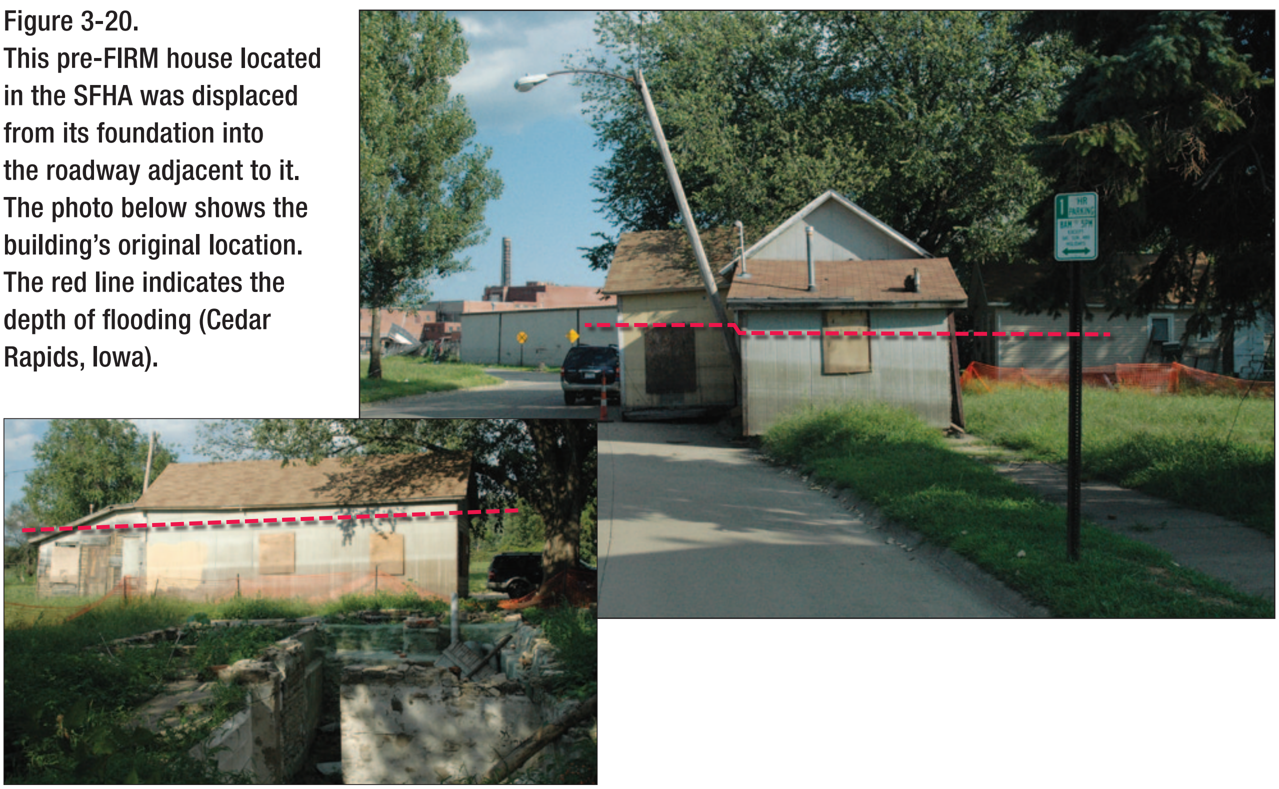
The flooding of the living areas in residences caused damage to the architectural finishes, cabinetry, insulation, ductwork, electrical system, and appliances to the extent that they will most likely need to be removed and replaced. The MAT also observed damage to the wood framing, nails, and insulation, and the presence of mold, as a result of elevated moisture levels in post-flood walls, as evidenced in Figures 3-18 and 3-19. Such extensive damage can result from delayed recovery efforts.

Figure 3-18.
Condensation can be seen beading up on the inside face of the vapor barrier (red circle). The increased humidity has initiated the growth of black mold (blue circle), started the rusting of the nails (blue arrow), and the wood is still wet as can be seen by the dark patches on the studs (red arrow) (Cedar Rapids, Iowa).

Figure 3-19.
The kitchen countertops, cabinets, appliances, etc., had been submerged and destroyed (Cedar Rapids, Iowa).

Some buildings located in the area of inundation were displaced from their foundations because they lacked sufficient connections to secure them. Figure 3-20 shows an older masonry foundation that did not have adequate connections to anchor the structure.

Figure 3-20.
This pre-FIRM house located in the SFHA was displaced from its foundation into the roadway adjacent to it. The photo below shows the building's original location. The red line indicates the depth of flooding (Cedar Rapids, Iowa).



The most common form of structural damage to residential buildings observed by the MAT was the failure of foundation walls, especially those constructed of unreinforced masonry, as a result of lateral pressures from saturated soils and hydrostatic pressure, as illustrated in Figures 3-21 to 3-27.

Figure 3-21.
Failure of unreinforced masonry foundation walls due to hydrostatic pressure observed in various locations in Iowa.

Figure 3-22.
Collapse of a foundation wall due to hydrostatic forces (Viola, Wisconsin).

Figure 3-23.
This foundation wall collapsed due to hydrostatic pressure (Reedsburg, Wisconsin).

Figure 3-24.
This basement wall failed and almost collapsed due to lateral pressures from saturated soils (Shell Rock, Iowa).

## DEFINITION

**Hydrostatic force** is a force exerted by water at rest, including lateral pressure on walls and uplift (buoyancy) on floors

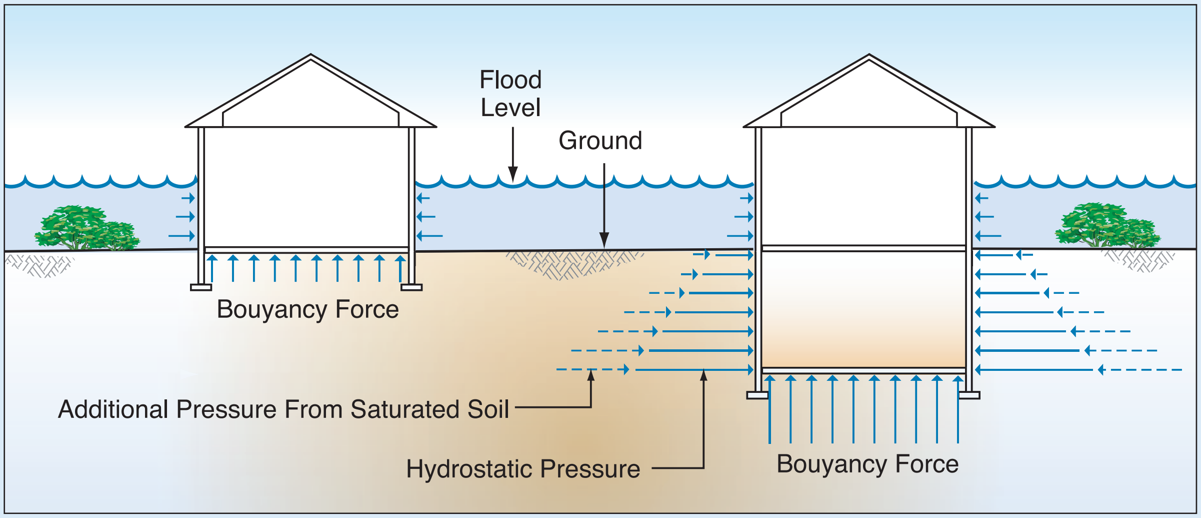



Figure 3-25.
This house had two walls that were damaged due to hydrostatic pressure (Reedsburg, Wisconsin).

Figure 3-26.
Example of a completed foundation wall repair that included vertical steel reinforcement and grout throughout the repaired wall to improve the strength and performance of the foundation (Waverly, Iowa).

Figure 3-27.
Interior view of the completed foundation wall repair in Figure 3-26; the owner stated that they placed horizontal steel reinforcement where possible along the top row of masonry blocks to create a bond beam. The yellow and blue lines are suggested reinforcing locations. This wall shows an alternative of external reinforcing of the wall using steel angles (red arrows) (Waverly, Iowa).

The IRC suggests a #5 bar every 48" for these masonry walls holding back 5 feet of fill not subject to hydrostatic pressure from groundwater. In the event that groundwater is in the soils in the unbalance backfill, the IRC requires engineering design. The reinforcing required to withstand 5 feet of water-laden soils is approximately a #5 bar every 16", or one per block, three times the number shown. Bond beams are recommended at all opening perimeters as well as at the top and bottom of the wall. Horizontal joint reinforcing should also be used every 16" vertically (blue dashes in Figure 3-27).

It is important to remember that repairing and reinforcing only the failed portions of a basement will not completely address weaknesses in the structure, and the basement will remain vulnerable to failure during future floods. In most homes with basements, all basement walls are constructed similarly and have similar strengths (see text box). When walls are similarly constructed, the relative performance of individual walls becomes a function of the loads applied to them and not of their strengths. Walls fail not because they are greatly weaker than adjacent walls but because the loads on them are greater. When a basement wall fails during a flood, the failure typically allows water to flow into the basement. Water filling a basement immediately reduces the forces on the remaining walls and essentially denies those walls the opportunity to fail. When basement walls are only partially reconstructed, the original walls that did not fail remain relatively weak and vulnerable during future floods.

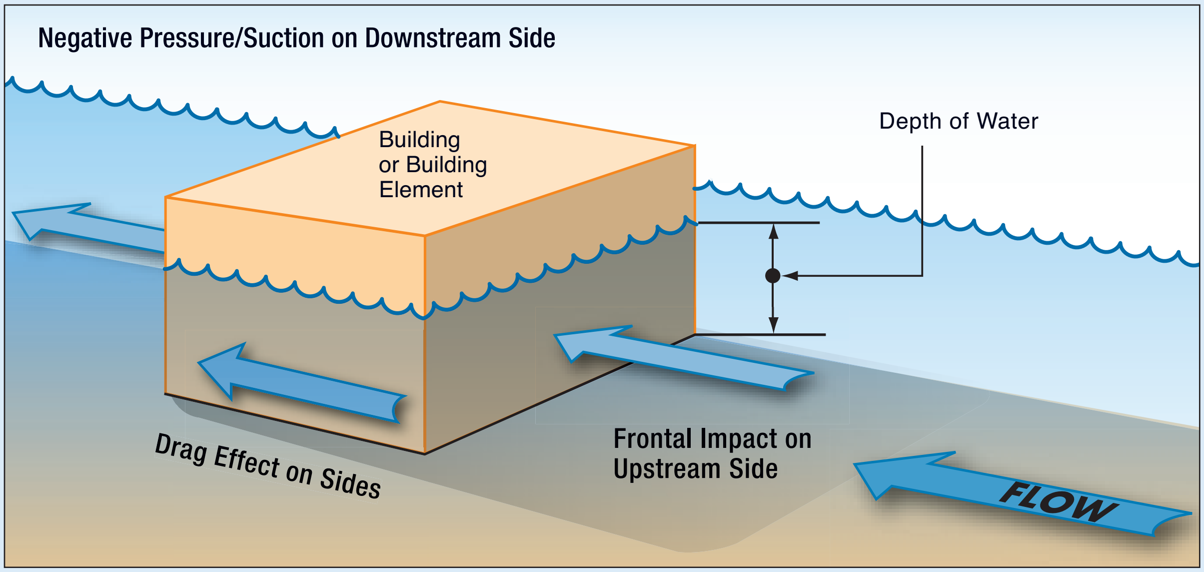
When basement walls fail, they typically fail in flexure, by trying to bend in toward the house. That is, their resistance to bending (flexure) is less than the *bending* caused by the lateral loads from floodwater and retained soils. Flexural stresses in a basement wall range from positive (compression) stresses on the outside surfaces of the walls and can become negative (tensile) stresses on the walls' inside surfaces. Since unreinforced masonry (and concrete) is inherently strong in compression but weak in tension most flexural failures are tensile failures.

Most structures visited by the MAT were impacted by water velocities that were slow enough that the buildings showed signs of inundation but not movement; however, there were occasional incidences of high-velocity flow that moved structures off their foundations. Buildings near breached or overtopped levees were most susceptible to high-velocity floodwaters that caused scour, carried large flood-borne debris, and imposed hydrodynamic forces that impacted the structural integrity of the building. In some areas, major structural damage resulted to both the foundation and the superstructure. Some structures were displaced from their foundations and driven into nearby spaces, roads, and the river. Figure 3-28 shows a house impacted by high-velocity floodwater.

**Figure 3-28.**
**The house on the left experienced high-velocity flow that passed through the lower level of the structure. The house on the right had living space at the same elevation, and the rear of the house was displaced. The red outline is the original location of the wall; the red arrow points to the location of the wall after the flood. This area experienced flooding that exceeded the estimated 0.2-percent-annual-chance flood (Coralville, Iowa).**

### DEFINITION

**Hydrodynamic force** is imposed on an object, such as a building, by water flowing against and around it.




Several homes experienced flows with sufficient velocity that the houses were displaced from their foundations and moved several yards, as shown in Figures 3-29 through 3-35.

Figure 3-29.
This garage was swept away and over the adjacent levee. The remnants of the garage are seen in the right edge of the inset (red arrow) (Waterloo, Iowa).

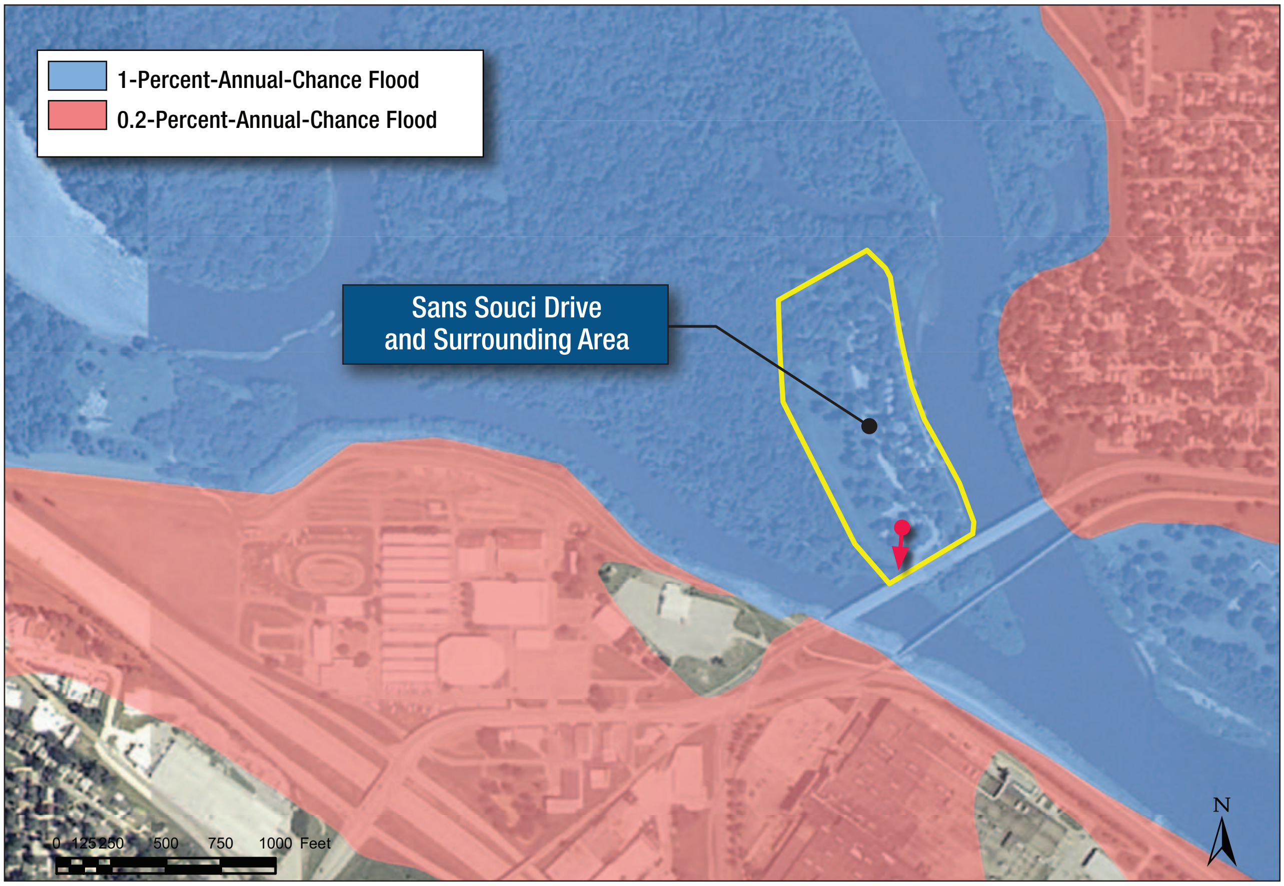



Figure 3-30.
The red arrow traces the path of the displaced structure shown in Figure 3-29. The debris field was found approximately 250 feet away from its origin (Waterloo, Iowa).

Figure 3-31.
This foundation wall was subject to scour caused by high-velocity flow after a levee was overtopped by floodwater (Oakville, Iowa).

Figure 3-32.
These failed connections were used to secure a home to a reinforced concrete foundation wall and were spaced every 6 to 7 feet (Oakville, Iowa).

Figure 3-33.
The home that was on this foundation was moved several hundred feet away by the floodwater that overtopped a levee (Oakville, Iowa).

Figure 3-34.
The home actually remained intact after being forced away from its foundation (this is the same manufactured home referenced in Figures 3-31 to 3-33) (Oakville, Iowa).

Figure 3-35. The framing for the portion of the home that remained in place was bolted down to the foundation (this is the same manufactured home referenced in Figure 3-31 through 3-34) (Oakville, Iowa).

Buildings constructed on open foundations in areas that experienced high-velocity flow remained in place and because they were generally elevated higher, suffered less damage. Figures 3-36 to 3-38 are examples of residential buildings constructed on open foundations. The buildings were located near the home that was relocated and illustrated in Figures 3-31 to 3-35.

Figure 3-36.
Residential building constructed on open foundation that suffered considerably less damage than those on closed foundations in the same area (Oakville, Iowa).

Figure 3-37.
Residential building constructed on open foundation that suffered considerably less damage than those on closed foundations in the same area. Slender columns such as those shown here offer little resistance to lateral loads that can occur from flooding and debris. Accounting for gravity and lateral loads, not just elevation, should be considered during design (Oakville, Iowa).

Figure 3-38. Residential building constructed on open foundation that suffered considerably less damage than those on closed foundations in the same area (Oakville, Iowa).

### 3.1.2 Residential Basements

Basements in the Midwest have traditionally been constructed as part of residential houses. They provide protection from tornadoes, aid in designing for frost depth, and provide additional usable space at low cost when part of the initial construction. However, their below-grade location makes them a liability during floods. Throughout the areas visited by the MAT, groundwater entered basements through pre-existing cracks and openings in the floors and walls (see Figure 3-39).

Because of their low elevation, it is difficult to keep water out of basements when the water level is higher than the basement floor. In addition, keeping water out is not advised because of potential structural damage caused by floodwater-saturated soil exerting additional pressure against basement walls. As discussed in the previous section, in several instances the basement walls failed due to hydrostatic forces. However, several homeowners indicated they opened basement doors and windows so that floodwater could readily enter and equalize the hydrostatic forces on the basement walls. The intrusion of floodwater resulted in significant damage to basement contents and walls, finishes, and floor coverings. In many homes, the mechanical and electrical systems were located in the basement for convenience and space concerns, and, as a result, the systems were severely damaged. Figures 3-40 and 3-41 show a displaced water heater and other utilities that were damaged due to flooding.

**DEFINITION**

**Basement** is defined as an area of a building having its floor sub-grade (below ground level) on all sides. The lowest floor of a residential building including basement must be at or above the BFE. Basements below the BFE are allowed only in communities that have obtained a basement exception from FEMA.

Figure 3-39.
Basement windows, like the ones on these houses, were typical locations for floodwater to enter a basement (Gays Mills, Wisconsin).

Figure 3-40.
This basement sustained damage to the mechanical and plumbing systems of the home (Waverly, Iowa).

Figure 3-41.
Basement located in a circa 1880s house. This basement has a furnace and other utilities that were inundated with 6 to 8 feet of standing water (Rock Springs, Wisconsin).

After a flood, homeowners should exercise extreme caution if their basement is inundated. Homeowners should not pump water out of a basement immediately following a flood. Even after the flood crest has passed and floodwater has receded, homeowners should avoid removing water from a basement too quickly so as to prevent basement wall and floor failure due to hydrostatic forces. Although most property owners impacted by the 2008 floods knew not to pump out their basements, Figure 3-42 provides an example of a basement that was pumped out too soon.

Figure 3-42.
This foundation wall collapsed when the homeowner prematurely pumped water out of the basement (Palo, Iowa).

The NFIP floodplain management criteria at 44 CFR §60.6(c) allow exceptions to permit construction of floodproofed basements along streams in certain flood zones and when flood characteristics throughout the community meet specified criteria (see Chapter 2).

The MAT visited La Porte City, Iowa, one of the communities approved for residential basement exceptions. The certified floodproofed basements visited had drainage systems with sump pumps and reinforced concrete walls and performed as designed with no structural failures observed or reported. Figure 3-43 shows a residential property with an engineered basement in La Porte City.

**Certified residential basements** are floodproofed with walls that are impermeable, walls and floors that are capable of resisting hydrostatic and hydrodynamic loads and the effects of buoyancy resulting from flooding, and designed so that minimal damage will occur from floods exceeding the floodproofing design elevation (which must be at least 1 foot above the BFE). These basements must be certified by a professional engineer or architect using FEMA form 81-78.

Damage in one newly engineered basement was reported by a homeowner where floodwater exceeded the floodproofing design elevation. These damages were in a basement just outside the SFHA (see Figure 3-44).

Figure 3-43.
Post-FIRM construction with a basement in a community approved for residential basement floodproofing. The basement performed as designed with a pump removing all flood and groundwater that entered (La Porte City, Iowa).

Figure 3-44.
This house located just outside the SFHA suffered no damage on the first floor (unlike the adjacent property), but the basement suffered damages to architectural finishes, electrical systems, and contents (Palo, Iowa).

It is important for communities to ensure basements are removed (unless properly approved) when substantially damaged properties are being elevated or reconstructed in the SFHA. Figures 3-45 and 3-46 are examples of completed and ongoing elevation projects where basements were kept in the SFHA.

Figure 3-45.
Completed elevation project where the basement was not removed; this violation was recorded prior to the 2008 floods (Coralville, Iowa).

Figure 3-46. Ongoing elevation of property located in the floodplain where homeowner was planning to keep the basement (Vinton, Iowa).

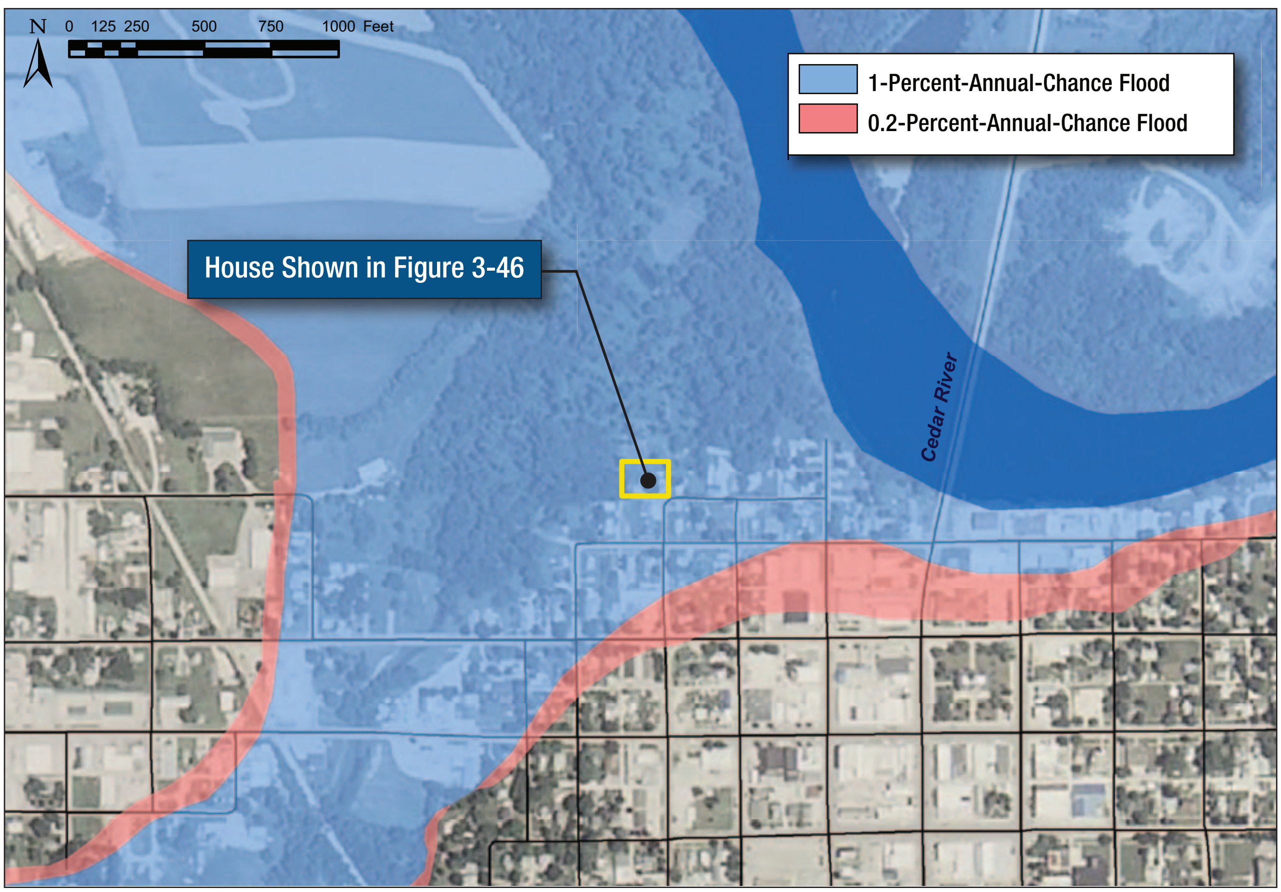



Figure 3-47. Location map for Figure 3-46 (Vinton, Iowa).

### 3.1.3 Residential Post-FIRM Elevated Buildings

The MAT visited numerous residential sites where owners had either already elevated their existing homes to avoid flooding or were in the process of doing so. Throughout Wisconsin, properties were elevated on fill two or more feet above the BFE (see Figure 3-48).

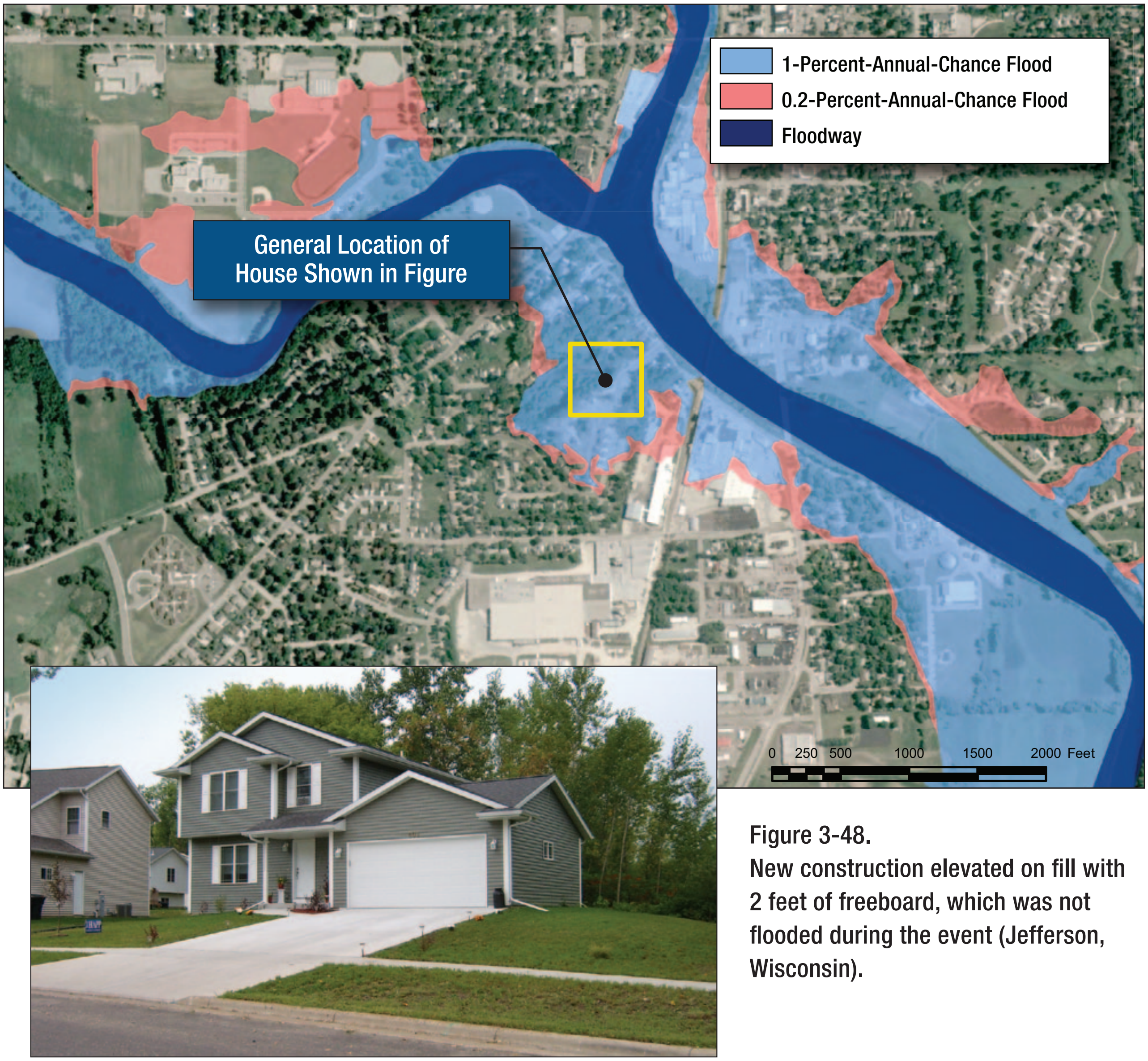



Figure 3-48.
New construction elevated on fill with 2 feet of freeboard, which was not flooded during the event (Jefferson, Wisconsin).

The Koshkonong, Wisconsin, community had several ongoing elevation projects of existing homes at the time of the MAT visit (see Figure 3-49).

Figure 3-49.
Existing house being elevated 2 feet above the BFE (Koshkonong, Wisconsin).

The MAT observed several elevated buildings in the SFHA without openings in their foundation walls that met the NFIP regulations. Several buildings did not have any openings while others either did not have enough or they were not at the proper elevation. The openings on the newly elevated house shown in Figure 3-50 are not within one foot of either interior or exterior grade as required.

Figure 3-50.
Recently completed elevation project, properly elevated above BFE; however, the foundation does not have openings at the proper height (red circles). The crawl space floor is at the same elevation as the exterior grade (New Hartford, Iowa).

Figures 3-51 through 3-57 illustrate additional observations made by the MAT related to openings that were not in compliance with NFIP regulations.

Figure 3-51.
This property, which was constructed not long before the Midwest floods, is elevated several feet above BFE and was the least damaged along a row of more than 50 riverfront properties (Iowa City, Iowa).

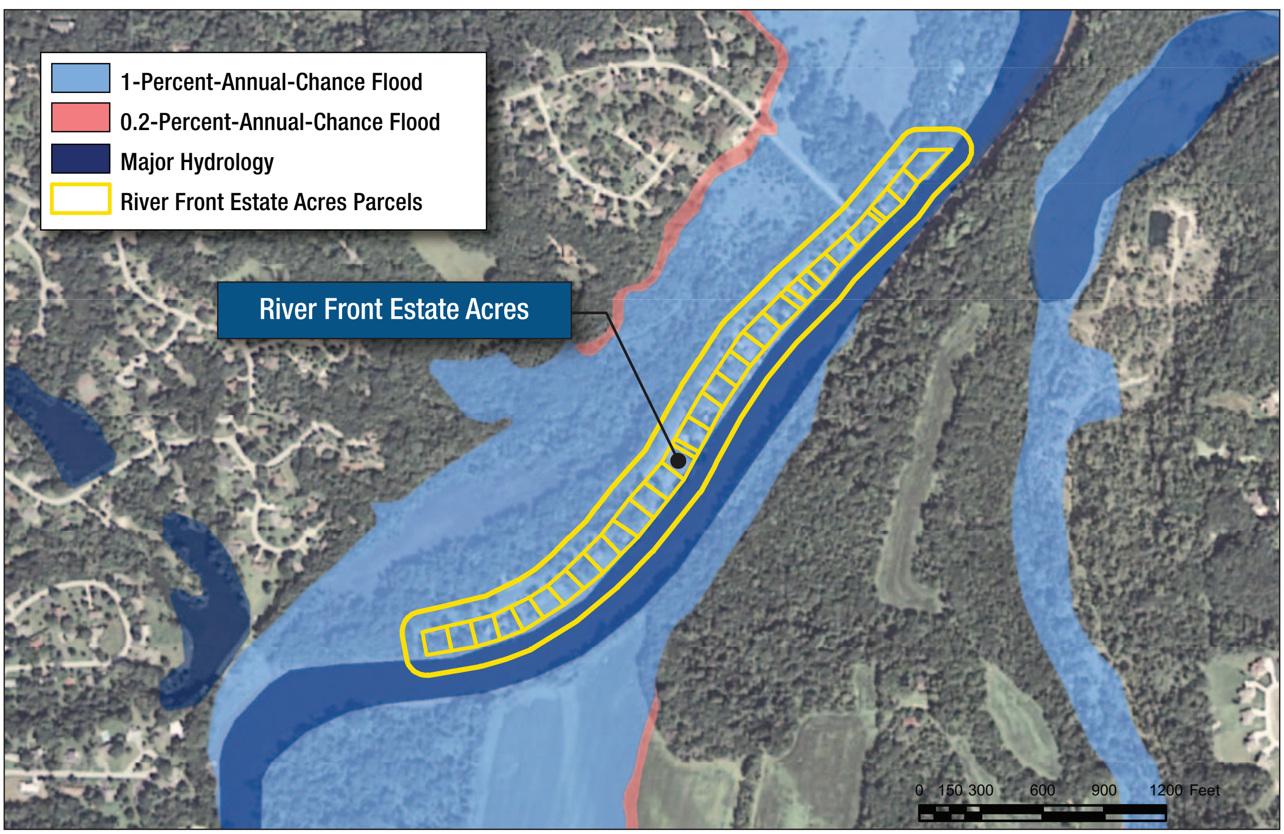



Figure 3-52.
The house in Figure 3-51 is located in River Front Estate Acres depicted above. The lots are located on the river's edge in the SFHA (Iowa City, Iowa).

Figure 3-53.
This riverfront house's two-car garage was one of only a few properties throughout the areas visited by the MAT with proper flood vent openings (Iowa City, Iowa).

Figure 3-54.
Unlike the garage, the riverfront house's flood openings were obstructed (Iowa City, Iowa).

Figure 3-55.
The homeowner had covered the openings on both the house and garage during the flood (Iowa City, Iowa).

Figure 3-56.
Foundation opening that does not conform to NFIP requirements for openings in foundation walls and walls of enclosures for structures in the floodplain (Blackhawk Island, Wisconsin).

Figure 3-57.
This house located in the SFHA had openings for ventilation of the crawl space, but were too high to be compliant flood openings (Gays Mills, Wisconsin).

Figure 3-58 shows an example of a house with openings at the proper height.

Figure 3-58.
This house located in the SFHA had openings installed within 12 inches of exterior and interior grade (La Valle, Wisconsin).

The MAT observed several ongoing elevation projects, most of which were being funded by the homeowner without federal grant or insurance money. In each case, homeowners were meeting their floodplain management ordinances for required elevation, and several were actually exceeding local requirements and elevating 2 to 3 feet higher to avoid future damages. Figures 3-59 through 3-62 illustrate observations at ongoing elevation projects.

Figure 3-59.
Existing house in the process of being elevated by homeowner (Cedar Rapids, Iowa).

Figure 3-60.
Most foundations were being built with anchor bolts to create a connection between the elevated house and the new foundation. For this project to be effective there must be a continuous load path and the use of frequently spaced reinforced cells in the block foundation walls. This house is located in the SFHA and is being elevated approximately 4 feet above the BFE (Iowa City, Iowa).

Figure 3-61.
This foundation has a well established layout for anchoring the sill plate. This connection is critical to the proper performance of the building in high-load events (Parkersburg, Iowa).

Figure 3-62.
Ongoing elevation of a property located in the SFHA where the foundation is prepared to establish secure connection between the foundation wall and the existing house. Upon completion, the house will have a crawlspace with openings at the proper elevation (Gays Mills, Wisconsin).

Local involvement in adoption of current building codes, strong floodplain ordinance regulation, and participation in acquisition programs appears to be an effective means of managing development in the floodplain. This is evidenced by the limited amount of new construction observed in the SFHA. Those buildings that are built in the SFHA are elevated above the BFE, i.e., with freeboard (see Figures 3-63 and 3-64).

Figure 3-63.
Structure in Reedsburg, Wisconsin, where the lowest floor is elevated 2 feet above BFE (red line shows the high water mark). The insert shows the interior of the adjacent pre-FIRM building had 3 feet of water above the first floor.

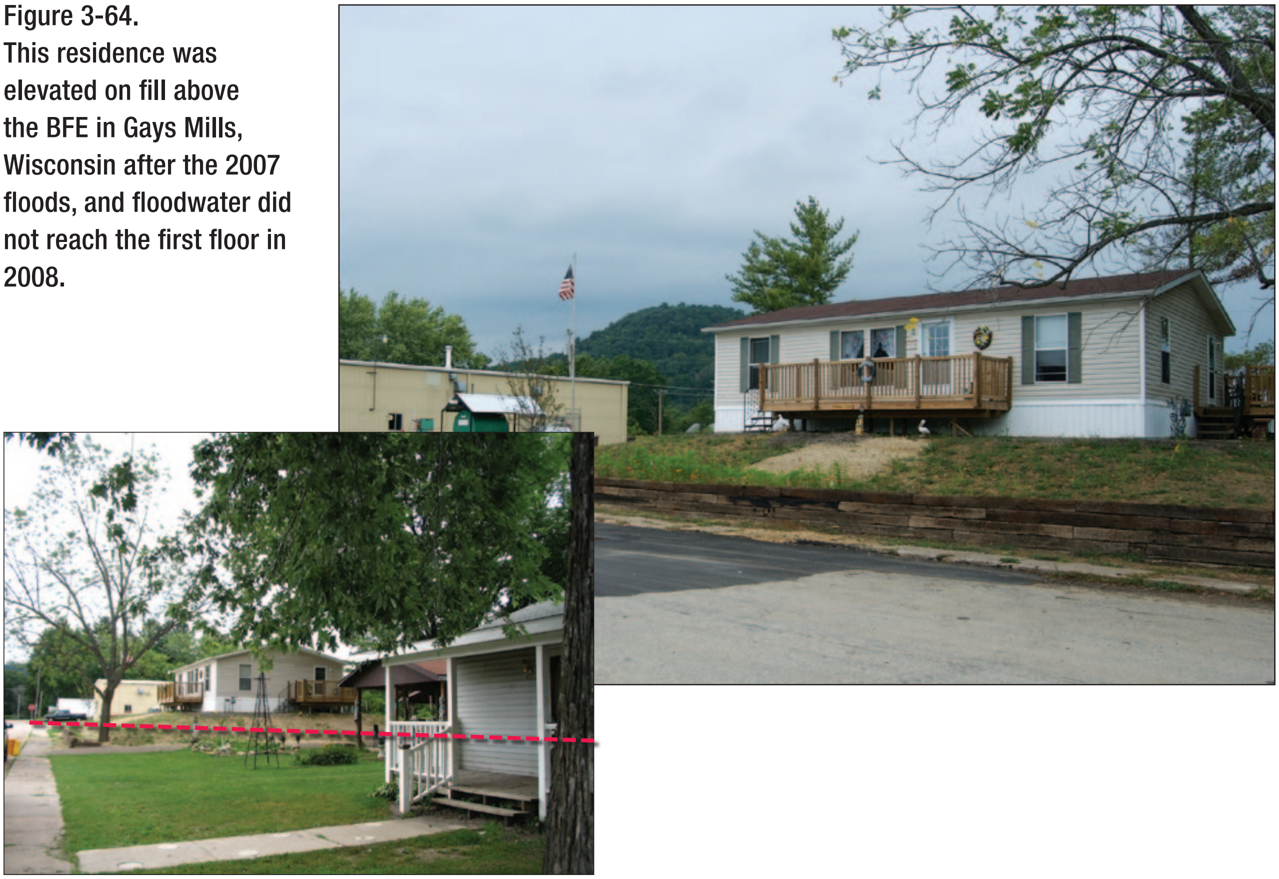


Figure 3-64.
This residence was elevated on fill above the BFE in Gays Mills, Wisconsin after the 2007 floods, and floodwater did not reach the first floor in 2008.

### 3.1.4 Residential Acquisitions

Since 1993, FEMA has funded more than 2,000 acquisition projects in Iowa and Wisconsin. The acquisitions were completed in conjunction with states and other federal agencies. These agencies and programs include the FEMA Hazard Mitigation Grant Program (HMGP), Flood Mitigation Assistance (FMA) program, Pre-Disaster Mitigation (PDM) program, the Community Development Block Grants through the Wisconsin Department of Commerce; Stewardship Funds through the Wisconsin Department of Natural Resources; and Municipal Flood Control grants through the Iowa Department of Natural Resources. In Iowa, the USACE has also had a prominent role in acquisition projects. The acquisition properties visited by the MAT clearly show that the programs had successfully removed residences from areas that would have been flooded during the 2008 floods and, if they had not been removed, they would have sustained significant damages. The acquisition projects visited were all within the SFHA. Given that the majority of the communities visited were impacted by a greater than 1-percent-annual-chance flood, the damages avoided by these acquisitions are estimated to be in the millions of dollars. Figure 3-65 shows the location of an acquisition project completed with federal mitigation funding made available after the 1993 floods.

Figure 3-65.
Site of a 1994 clearance project where multiple residential structures were acquired under the FEMA HMGP. This area is in the SFHA. Based on observed high water marks, it is estimated the acquired buildings would have had at least 1 foot of water in them (Independence, Iowa).

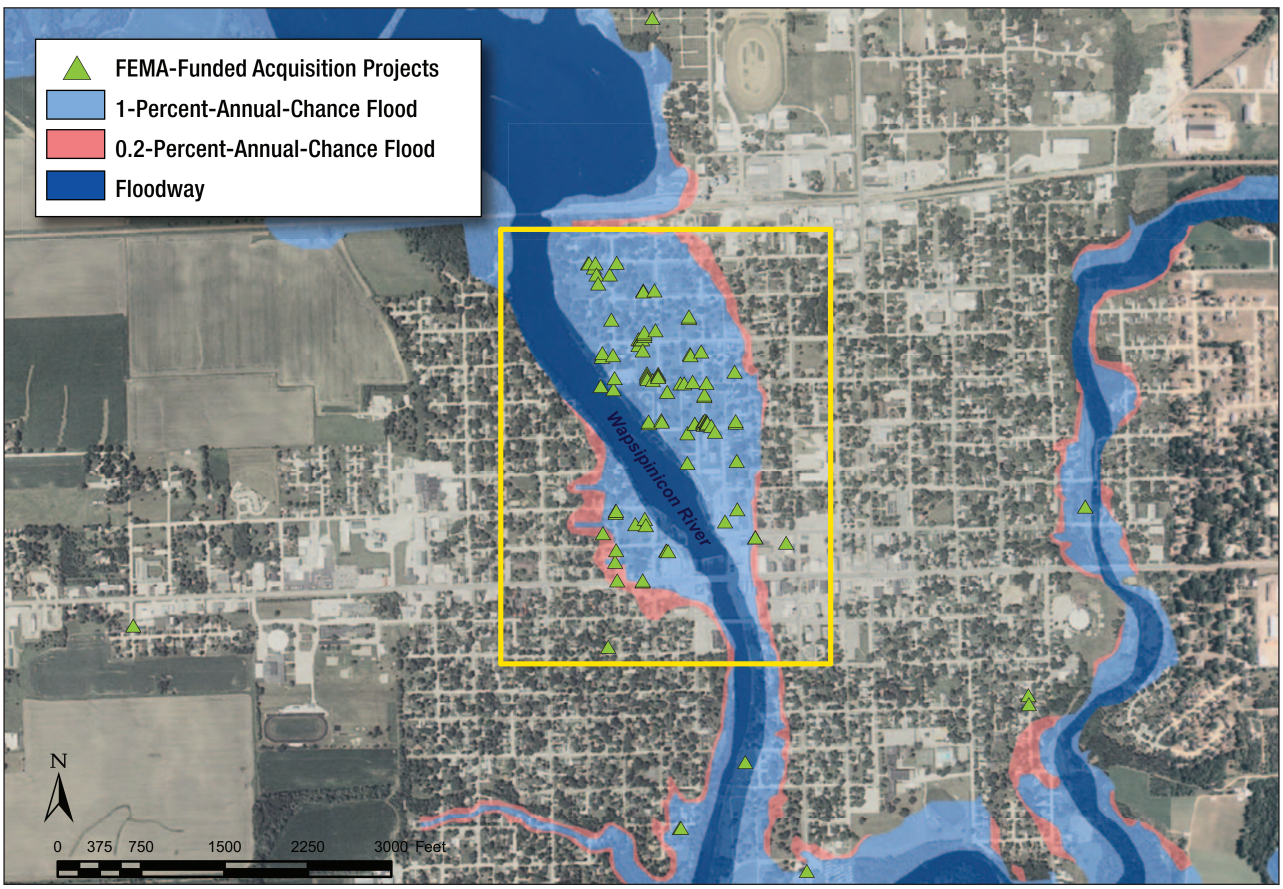



Figure 3-66. Location map for Figure 3-65 (Independence, Iowa).

When conducting wide-scale acquisition and relocation projects, it is important to consider long-term plans for the area. This helps ensure that homes subject to future flood damages do not remain and that they are not acquired and relocated or elevated in a random fashion. FEMA 317, entitled *Property Acquisition Handbook for Local Communities*, addresses such issues and lays out a framework to help communities successfully implement property acquisition projects. A patchwork approach to acquisition can lead to homes remaining in the neighborhood that are isolated between vacant lots. The effect of raising some homes within a floodprone area while others are acquired may create a strain on public services, utilities, and emergency access and response. In addition, any isolated homes may be eligible for future mitigation assistance such as elevation that may not be consistent with the need for a community to permanently vacate such areas in order to reduce the cost of providing perpetual infrastructure services and mowing and maintaining the vacant lots. Figure 3-67 shows the benefit of long-term planning versus a patchwork approach. Having a few remaining structures within such multiple vacant lots does not allow the conversion of the vacated lots into a sustainable use such as ecosystem restoration and/or open space based recreation.

**Figure 3-67.**
**The top photos show a project where the community acquired and relocated multiple residences in the SFHA. The lower left image is one of a few sporadic completed elevations in the same area, and the lower right is an ongoing elevation project (Cedar Falls, Iowa).**

A majority of the acquisition projects observed by the MAT were funded by FEMA and other federal agencies. In addition, some communities budgeted funding to finance mitigation projects internally. For example, the Milwaukee Metropolitan Sewage District Flood Management Program manages over $100 million annually for mitigation projects through funding collected from sewage disposal fees. The projects include creating increased temporary water storage, improving the sewer system to avoid backups during floods, and acquiring developed property to convert land use to open space or undeveloped property to ensure it remains open (see Figure 3-68).

**Figure 3-68. Site of successful acquisition of several houses in the SFHA. The acquisitions were completed using local funds to convert the area to open space. Had the houses remained in place, they would have been impacted by 1 to 2 feet of flooding in 2008 (Milwaukee, Wisconsin).**

## 3.1.5 Residential Properties – Other

### 3.1.5.1 Letter of Map Revision Based on Fill (LOMR-F)

The Idyllwild subdivision in Iowa City was built on fill approximately 10 to 15 years ago (see Figures 3-69 through 3-72). As shown in Figure 3-70, this area was originally mapped in the regulatory floodplain. However, fill was added to this subdivision site through a LOMR-F to raise the land elevation and remove it from the regulatory floodplain. A LOMR-F is FEMA's modification of the SFHA shown on the FIRM based on the placement of fill outside the existing regulatory floodway. All requests for changes to effective maps, other than those initiated by FEMA, must be made in writing through the Chief Executive Officer (CEO) of the

> FEMA recognizes that changes will be required on the flood maps and has a mechanism for addressing them. One method for addressing a change to the floodplain is via the Letter of Map Revision (LOMR) process. The presence of a LOMR simply indicates a reduced risk and removes the regulatory flood purchase requirement for mortgages in the area covered by the LOMR. It does not guarantee the area will not be flooded. The fact that it was previously mapped in the SFHA is evidence of potential flood risk.

community or an official designated by the CEO. Because a LOMR-F officially revises the effective NFIP map, it is a public record that the community must maintain. Any LOMR-F should be noted on the community's master flood map and filed by panel number in an accessible location.

Although most of the development was considered outside the floodplain based on a LOMR-F, it suffered extensive damages. (The LOMR-F is not reflected on the map shown in Figure 3-70.) The community spent over $2 million in initial clean up costs to remove damaged contents and prevent further damage (e.g., mold); repair estimates require an additional $10 million from property owners.

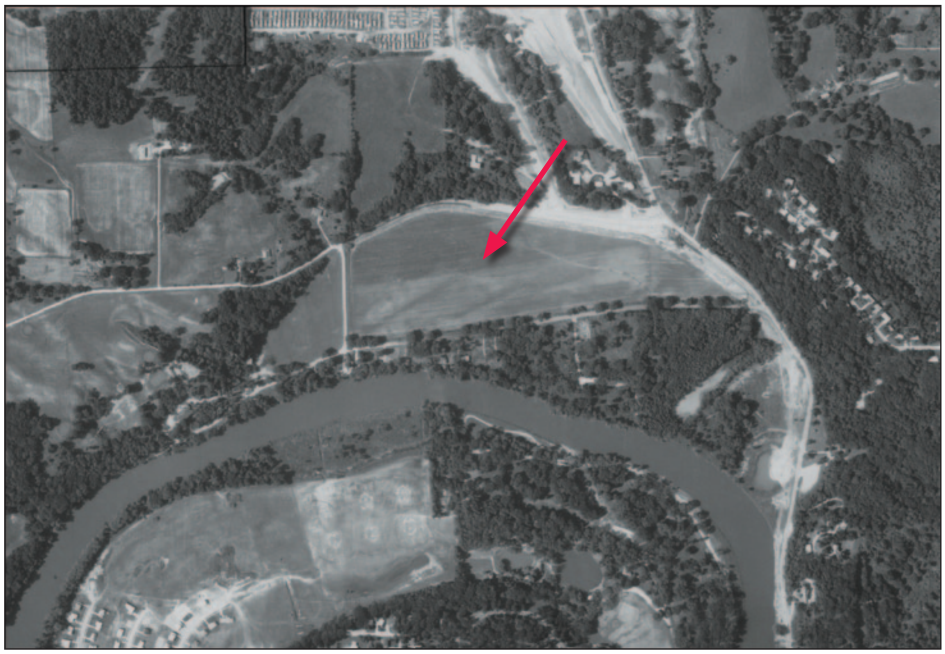


**Figure 3-69.**
**This is the historic Coralville area circa 1960 from U.S. Department of Agriculture archives. The red arrow indicates the location of the flooded subdivision (Iowa City, Iowa).**

Two months after the flood, only one residence out of more than 90 residences in the subdivision was occupied. This residence had all living areas located on the second floor along with the hot water heater, air handling unit, laundry room, and kitchen, which illustrates the benefits of careful selection of these locations to ensure building performance during a design level event. The adjoining single-story unit was inundated with 3 to 5 feet of floodwater and suffered 2 to 3 times the economic losses (see Figure 3-72).

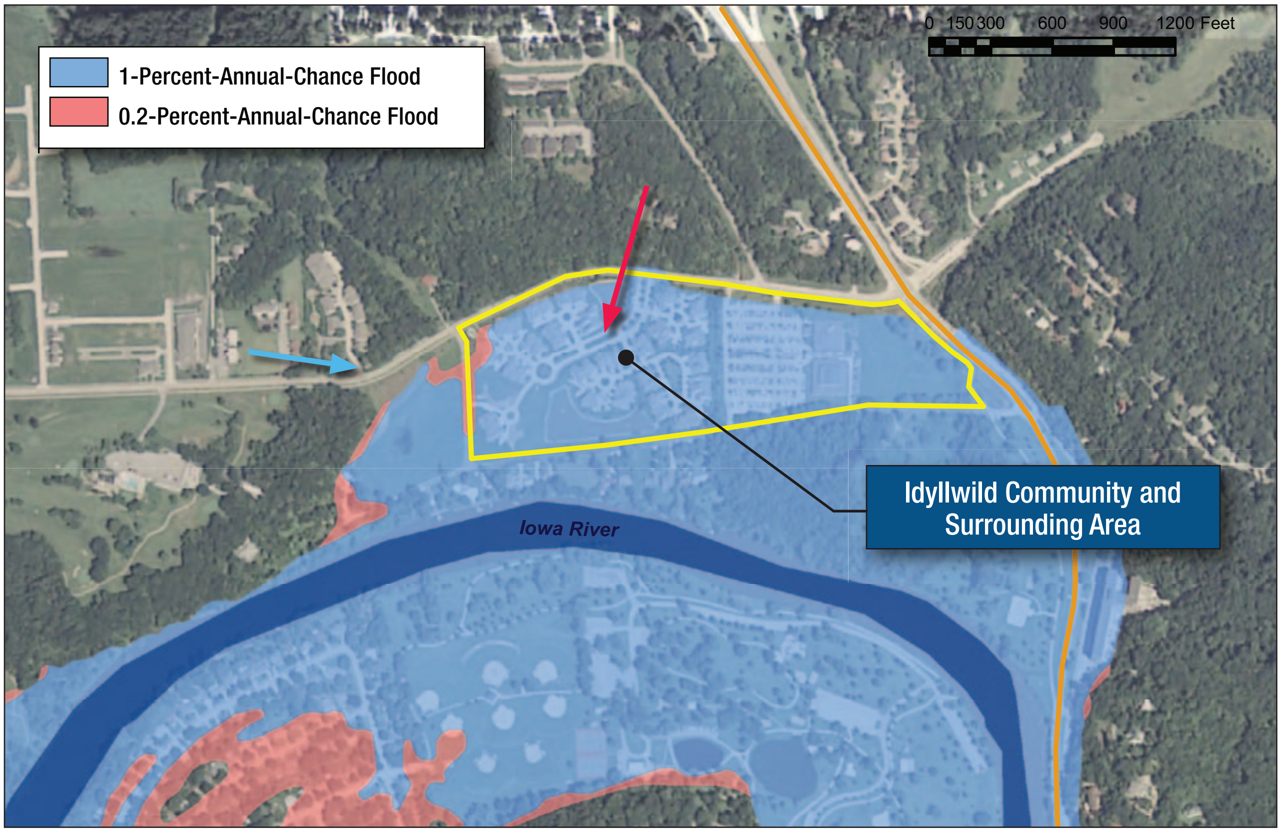



Figure 3-70.
This is the Idyllwild community (see red arrow) shown relative to the natural floodplain with the 1-percent and 0.2-percent-annual-chance floodplains highlighted without the elevation on fill being taken into consideration. The blue arrow is the position that the upper left photo in Figure 3-72 was taken from. This area experienced a <0.2-percent-annual-chance flood (Iowa City, Iowa).

Figure 3-71.
This is the Idyllwild community (see red arrow) shown during the flood event. The red arrow is the location of the house shown in Figure 3-72 (Iowa City, Iowa).

Figure 3-72.
Site of a subdivision built on fill during the early 1990s, considered outside the floodplain based on LOMR-F. The dashed line in the upper right photo indicates the floodwater level. The center right and left photos show utilities located on the second floor level of the residence in the upper right photo. The bottom photos illustrate interior damage to the adjacent properties. The upper left photo was taken from the position noted in Figure 3-70 (Iowa City, Iowa).

One challenge noted by the MAT was the difficulty in repairing the party-wall between units in the Idyllwild community. The party-wall was constructed in three layers (see Figure 3-73). The gypsum wallboard was applied to each layer successively. Then the next portion of framing and another layer of gypsum wall board were installed. The floodwaters damaged all the layers of the drywall in the party-wall. The damaged material can be broken down and easily removed. New material comes in 4-foot by 8-foot or 4-foot by 12-foot sheets. But since the spacing between studs is 16 inches, there is no practical way to replace the inner sheets.

Figure 3-73.
The majority of the units throughout the subdivision were uninhabitable two months after the event; several issues regarding re-occupancy will need to be resolved such as repair of the firewall system dividing the units (Iowa City, Iowa).

Another difficulty is that the newly removed wall board creates a single continuous open corridor between all units. With some units being ground level garden units and others being two-story units, the living space of some units is now open to the adjacent garage and automobiles. Re-occupancy of these units should be carefully monitored to ensure that life-safety and security issues are not compromised in the interest of rapid recovery.

The experience of the Idyllwild community underscores the importance of communicating risk even for areas that are considered to be outside the floodplain and the need for property owners to consider carrying flood insurance in these areas, something the homeowners association had contemplated in the late 1990s. In addition, it illustrated the advantages of designing buildings so that the more expensive components (such as the kitchen and utility room) are located on upper floors and the lower floors are restricted to open or storage space, especially in areas where there is a residual risk of flooding.

### 3.1.5.2 Storage Tanks

The NFIP requires that storage tanks be elevated above the BFE or be made watertight and anchored to resist floatation, collapse, or lateral movement resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy. The MAT observed numerous storage tanks throughout the communities visited that were not properly secured (see Figure 3-74). These unanchored tanks not only create more debris, but also generate a serious threat to public safety and the environment.

**Figure 3-74. Improperly anchored storage tanks in the SFHA (North Freedom, Wisconsin, and Iowa City, Iowa).**

### 3.1.5.3 Boat Houses

The Ellis Boat Harbor is located in Cedar Rapids along the Cedar River with structures on the water. Prior to the 2008 floods, there were over a hundred homes in this area, but several of the houses were forced downstream during the flood, crashing into a railroad bridge downstream. The anchoring systems were insufficient to secure the structures, and almost half of the houses became floodplain debris (see Figures 3-75 to 3-78).

These anchorages were welded to the face of a light steel sheet pile section. Marine anchorages typically need to be positively tied into an anchor wall or dead-man system. These anchor points need to be designed to maintain their design capacity after years of corrosion similar to the design of a steel sheet pile bulkhead. All possible loading conditions need to be considered when designing these structural components. The height of the water aggravated the condition when relatively short ramps/ties were used. The ramps folded under the boat house generating tremendous prying forces.

Figure 3-75.
Typical boathouse in the Ellis Boat Harbor. Red arrows point to damaged anchorages (Cedar Rapids, Iowa).

Figure 3-76.
If these boat houses remain, these anchorages should be much more robust and tied into more of the upland structure such as an anchor wall or dead-man system and help avoid damage to the bulkhead (Cedar Rapids, Iowa).

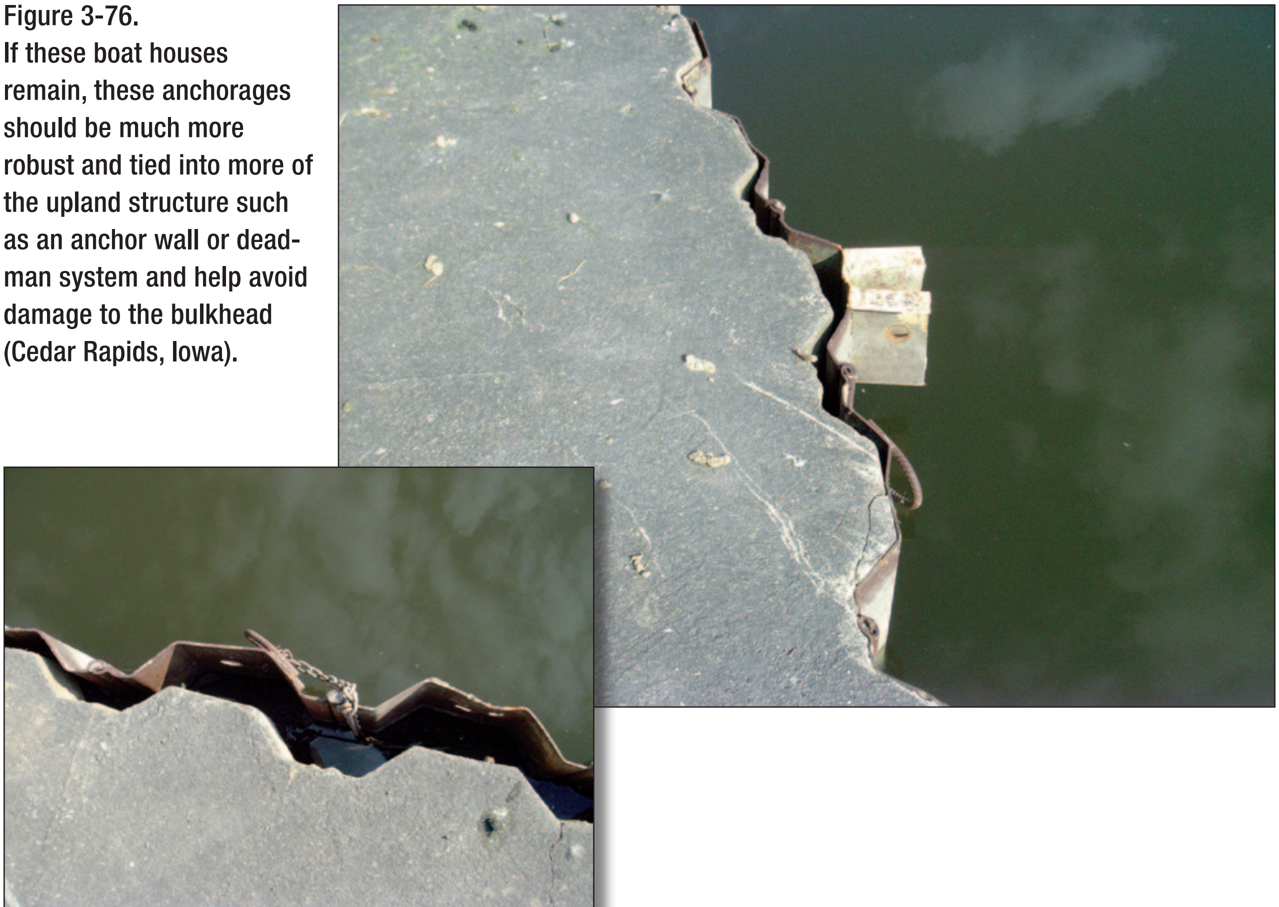


Figure 3-77.
About half of the houses were forced loose by the flooding and had to be recovered throughout the floodplain (Cedar Rapids, Iowa).

Figure 3-78.
Several houses were displaced downstream against a railroad bridge (Cedar Rapids, Iowa).

## 3.2 Historic Buildings

Mitigation and recovery strategies for historic buildings and structures should be designed to preserve the historic character of the properties. Assistance with this process can be found in *The Secretary of the Interior's Standards for the Treatment of Historic Properties with Guidelines for Preserving, Rehabilitating, Restoring and Reconstructing Historic Buildings* (Secretary of Interior Standards) from the Department of the Interior Guidelines for the treatment of historic properties, which is available at the following websites: http://www.nps.gov/history/hps/tps/tax/rhb/stand.htm and http://www.nps.gov/history/hps/tps/tax/rhb/guide.htm.

Additional resources can be found on the National Institute of Building Sciences website, most importantly, the *Whole Building Design Guide*. The information in the guide specific to historic preservation can be found at http://www.wbdg.org/design/historic_pres.php.

Many historic buildings in the Cedar Rapids Bohemian Area were inundated by waters from the 2008 Midwest floods. These buildings typically had basements. The core elements of these structures performed well due to the favorable material properties and the methods of construction. The heavy construction helped basement walls to resist the unbalanced lateral loads from saturated soils. See Section 3.1.1 for more information on behavior and performance of materials.

These buildings are typically constructed of multiple courses of unreinforced stone masonry and/ or unreinforced clay masonry, and heavy timber framing and dimensional lumber sheathings. See Figures 3-79 and 3-80 for typical masonry construction and wood framing details.

Figure 3-79. This historic building (C.S.P.S. Hall) withstood approximately 8 feet of water (red line). This property, in an A11 flood zone, has a BFE of 722 feet, and a building elevation of approximately 720 feet (Cedar Rapids, Iowa).

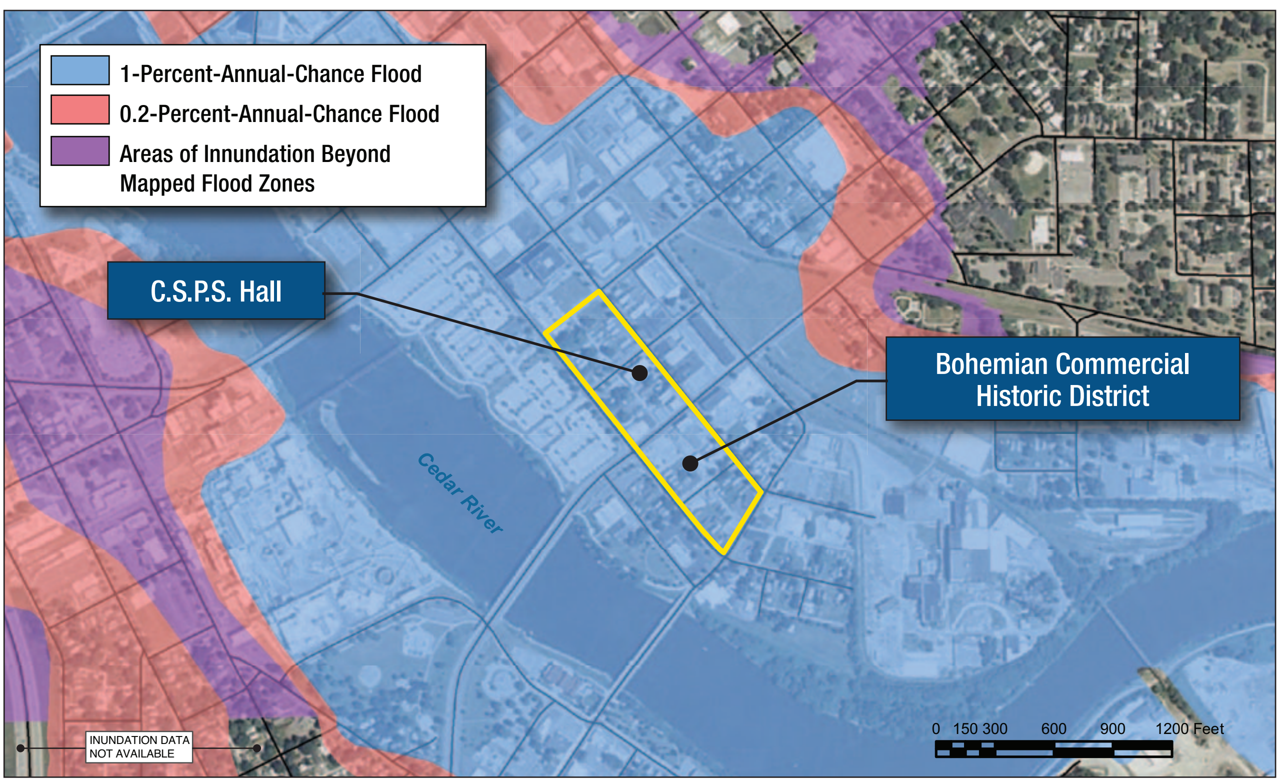



Figure 3-80. Cedar Rapids Bohemian Commercial historic district (Cedar Rapids, Iowa).

Care must be taken to use compatible materials when repairing historic structures or damage may result. Modern cement mortars have the potential to have different mechanical properties, such as elasticity or stiffness, than the original parent material and can lead to damage of the masonry elements at the base of the building.

The foundation for the C.S.P.S. building appears to be in good condition after being dried out for several months. The hand-hewn stone cap block is in perfect condition. Effort should be made to dry-out and dehumidify the basement after this inundation, to ensure the wood framing returns to acceptable moisture content (see Figure 3-81).

Figure 3-81.
Basement and foundation of historic building. The chisel marks in the hand hewn capstone (red arrow) are physical representations of the historic context of the building, the stone having been sized manually versus utilizing machinery (Cedar Rapids, Iowa).

A historic fire station experienced relatively little damage in spite of being inundated by floodwater at a similar height as floodwater that damaged adjacent buildings. This was due to the unusual interior materials used in the first floor of this building. The ground floor interior was finished in glazed brick, likely as a result of the need to clean and dry the fire equipment during all seasons, especially the winter. Thus the brick work served as a water-resistant material for routine maintenance operations, and it resisted the floodwater as well (see Figures 3-82 and 3-83).

Figure 3-82.
This historic fire station's damage was limited to some broken windows and a damaged overhead door (Cedar Rapids, Iowa).

Figure 3-83.
The interior ground floor of this historic fire station was designed with glazed brick. This effectively wet floodproofed the building (Cedar Rapids, Iowa).

The interior finishes located on the first floors of these flooded historic buildings typically did not fare well during the flooding. The flooring, trim, wall coverings, plaster, and drywall finishes were damaged by inundation. Replacement materials should be "in-kind" (of the same, or visually compatible, materials), following the guidelines and approaches recommended by the SOI Standards. These elements, which will need to be replaced, have been removed to allow the underlying structural components to dry. Care must also be given to treatment for decay and for wood-destroying organisms. A treatment and monitoring program should be implemented to verify these areas are properly de-humidified and no decay occurs. The damaged mechanical and electrical systems located on the first floor had to be replaced. Consideration should be given to locating the replacement equipment above the first floor, when possible and appropriate, to avoid future damage from flooding, as shown in Figures 3-84 and 3-85.

Figure 3-84.
This historic building had loss of the first floor furnishings, mechanical systems, electrical systems, and finishes due to 8 feet of water inundation (red line). This property, within the SFHA, has a BFE of 722 feet, and an elevation of approximately 720 feet. The upper floors survived intact (Cedar Rapids, Iowa).

Figure 3-85.
The interior of the restaurant lost all interior elements up to about 8 feet above the floor (red line) (Cedar Rapids, Iowa).

## 3.3 Commercial Facilities

The team surveyed commercial facilities ranging from offices and retail shops to a swine food processing plant. All of the commercial facilities discussed in this section are classified as Category II structures as defined in ASCE 7, *Minimum Design Loads for Buildings and Other Structures,* cited at the beginning of this chapter. Similar to most of the residential properties, commercial facilities were inundated with slow rising inundation. Figure 3-86 illustrates buildings within the SFHA in Gays Mills that were flooded by water that exceeded a 1-percent-annual-chance flood. On the other hand, Figure 3-87 illustrates a once similar area upstream along the Kickapoo River that was converted into open space with the buildings relocated to higher ground.


Figure 3-86. The Gays Mills downtown district had over 6 feet of water from the flood (Gays Mills, Wisconsin).

Figure 3-87. Upstream of Gays Mills along the Kickapoo River, this open space was once downtown Soldier's Grove before the community began relocating after significant flooding in 1978. In 2008, the park was inundated and repaired; however, the damages would have been much greater had the community not relocated (Soldiers Grove, Wisconsin).

Three examples highlighted in the following sections illustrate the damage to, and the functional losses of, a manufacturing plant, a commercial district, and an office building.

### 3.3.1 TriOak Foods Processing Plant, Oakville, Iowa

**Overview:** Oakville, Iowa, is home to the headquarters of TriOak Foods, a grain and pork processing company with facilities throughout the state. The Oakville complex includes several slab-on-grade, metal frame buildings that house corporate offices, a swine processing plant, and grain storage and shipping facilities. TriOak Foods, like much of Oakville, is located behind a levee; when the levee was breached, the plant flooded with over 2 feet of water. Most of Oakville remained inundated for three weeks before the floodwater receded.

**Summary of Damages:** Although TriOak Foods buildings incurred some minor architectural damage, storage equipment bore the brunt of the flood damage:

- Two underground, un-anchored, 10,000-gallon fuel tanks floated up from beneath a 4-inch concrete slab as shown in Figure 3-88. The Petroleum Equipment Institute publication *Recommended Practices for Installation of Underground Liquid Storage Systems* (RP100-05), which is cited in 40 CFR 280.20 (d) (ii), has recommended procedures for anchorage of these type tanks.
- Only pieces of a dry-storage wall remain upright; much of the wall was knocked over as shown in Figure 3-89.
- Metal feed silos constructed with bolted connections experienced some seepage resulting in damaged feed as shown in Figure 3-90. Welded feed silos did not have seepage issues.

Figure 3-88.
Water seeping into the ground generated enough buoyancy to force two 10,000-gallon underground fuel storage tanks through a 4-inch concrete slab at the TriOak Foods plant (Oakville, Iowa).

Figure 3-89.
A dry-storage wall was destroyed at TriOak Foods (Oakville, Iowa).

**Functional Loss:** Swine were evacuated during the flood. Although there was minimal damage to buildings, the plant remained closed for the duration of the flood and cleanup process. The damage to the fuel tanks could potentially lead to very expensive environmental cleanup efforts. Anchoring of any above or underground fuel tanks is recommended as well as placement and anchoring of above ground tanks in secondary retention structures.

Figure 3-90.
Bolted silos like the one at right at TriOak Foods were prone to seepage; as a result, some feed was lost. Welded silos like the one at left did not experience seepage (Oakville, Iowa).

## 3.3.2 Urban Commercial Buildings, Cedar Rapids, Iowa

**Overview:** Cedar Rapids has had several construction booms since its founding in 1841. As a result, commercial buildings in downtown Cedar Rapids represent a variety of construction types and periods. Significant periods of growth and construction occurred during the 1800s, the early and mid-1900s, and the 1980s. There are also several buildings constructed in the late 1990s.[1] See Figure 3-91 for a picture of downtown Cedar Rapids during the flood.

**Summary of Damages:** According to residents, the Cedar River inundated 1,300 blocks and 9.2 square miles of the city on both sides of its banks. Flooding affected the commercial, municipal, and industrial districts, among others. Throughout the downtown area, water depths of 7 to 8 feet were observed.

Most buildings experienced significant flooding in their basements and first floors, resulting in severe damage to interior architectural finishes and contents. Few structural failures were observed.

Cedar Rapids also has several parking structures that include sub-grade levels with basement access from the parking garage to buildings they connect with. Many of these parking structures and the basements of attached buildings experienced flooding.

**Functional Loss:** Approximately two months after the water crested, most commercial buildings had not recovered and were not functioning or occupied. Many cultural and public use buildings had

1 "Open House Presentation Boards." *Cedar Rapids Downtown Area Plan.* http://www.cedar-rapids.org/community/documents/open_house/all%20boards.pdf 15 November 2007

also suspended operations. The Paramount Theatre, the Cedar Rapids Science Museum, and the Cedar Rapids Public Library facilities were all flooded; the library may not resume function in its original location for up to three years.[2]

Figure 3-91. The Cedar Rapids downtown district had up to 8 feet of water at the height of the flood (Cedar Rapids, Iowa).

### 3.3.3 Great American Building, Cedar Rapids, Iowa

**Overview:** The Great American Building, a commercial office building, was built on the riverside in 1998 as shown in Figure 3-92. The building has a flood response plan, required by its insurance policy that includes plugging floor drains and sandbagging entrances. Although the plan was followed, rapidly rising water overwhelmed response and recovery efforts.

**Summary of Damages:** The slab-on-grade structure had 7.5 feet of water on the first floor, which resulted in an estimated $2 million in damages to interior finishes and utilities, including electrical equipment and wiring, fire pumps, and the emergency generator. The only damage to upper level offices was due to one office's equipment malfunctioning when power was shut off—that damage was minimal. This office building plans to restore all damaged equipment to its pre-flood location.

**Functional Loss:** Water entered only the first floor; however, offices on upper levels were unable to resume operations for several weeks until after the electrical components on the first floor were repaired.

2 Cedar Rapids Public Library web site. http://www.crlibrary.org/flood/index.html

Figure 3-92.
The Great American Building sits along the Cedar River. Although it had a flood response plan in place, it experienced significant flooding on its ground floor. This property, in an A11 flood zone, has a BFE of 724 feet, and an elevation of approximately 720 feet (Cedar Rapids, Iowa).